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BASE LINE ENVIRONMENTAL INVESTIGATION DREDGING ACTIVITIES, MOBILE BAY, ALABAMA

Technical Committee for Analysis of Mobile Bay Dredging
Mobile, Alabama

May 1972

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A PROGRESS REPORT OF THE
TECHNICAL COMMITTEE
ANALYSIS OF MOBILE BAY DREDGING
August, 1972

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U S Department of Commerce
Springfield VA 22151

Prepared for
The Conferees of the January 27-28, 1970
Conference "In the Matter of Pollution
of the Navigable Waters of Mobile Bay
and Its Tributaries"

A PROGRESS REPORT OF THE TECHNICAL COMMITTEE ANALYSIS OF MOBILE BAY DREDGING

August, 1972

TABLE OF CONTENTS

Section		Title	Page
		List of Tables	i
		List of Figures	ii
I		Introduction	1
II		Summary and Conclusions	5
III		Recommendations	9
IV		Description of Study Area	11
V		Study Program	13
	A.	EPA Criteria	13
	B.	Study Objectives	13
VI		Resurvey of State Sampling Stations	17
VII		Sediment Sampling Program	22
	A.	General	22
	B.	Core Sampling Methods	27
	C.	Methods For Analyses of Samples	30
	D.	Summary and Comparison of Results For Parameters Having Established EPA Guidelines	31
	E.	Summary of Results For Other Parameters Determined	35
	F.	Discussion of Results	36
	1.	Relationship of Sediment Type to Concentration of Pollutants	36
	2.	Other Observations	42

TABLE OF CONTENTS
Continued

Section	Title	Page
VIII	Evaluation of Deep Core Samples	47
IX	On-Going Studies: Water Quality Aspects of Typical Dredging Projects in Mobile Bay	54
A.	Open-Water Disposal	54
B.	Diked-Land Disposal	56
C.	Channel Construction in an Undisturbed Area of the Bay	67
D.	Buried-Reef Shell Dredging	69
X.	Bibliography	79

LIST OF TABLES

Table No.		Page
1	Concentration of Selected Elements in Bottom Sediments of Mobile Bay and its Tributaries	19
2	Comparison of Sediment Analyses from Mobile Bay and Tributaries - 1970 & 1971	21
3	Mobile Bay Sediment Data - 1971	23-25
4	Comparison of Core Boring Results with EPA Guidelines for Open-Water Disposal	32
5	Stations South of Causeway Grouped By Sediment Type (Surface Samples Only)	39
6	Bay Stations in order of Total Weighted Rank for Eight Parameters Measured at the Mud Surface	40
7	All Stations in order of Total Weighted Rank for Eight Parameters Measured at the Mud Surface	45
8	Pollutant Concentration at Specific Depths from Deep Cores	50
9	Average Concentrations - Diked-Land Disposal Samples	63
10	Shell Dredge Water Samples	70
11	Progress on Project Study Units	77-78

LIST OF FIGURES

Figure No.		Page
1	Location of Sampling Stations	18
2	Hand Driven Piston Corer	29
3	Distribution of Sediments in Mobile Bay	38
4	Contamination Levels at Bay Stations as Related to Distance from Causeway	44
5	Sediment Distribution in Bore Hole W-7 Mobile Bay Delta	49
6	Sediment Distribution in Bore Hole W-6 Mobile Bay Delta	52
7	Diked-Land Disposal Sample Collection Plan	58

I. INTRODUCTION

The Federal Water Pollution Control Act, as amended, provides that, upon request of the Governor of a state, an Enforcement Conference may be called by the Administrator of the Environmental Protection Agency (formerly by the Secretary of the Interior) if it is determined that economic injury results from the inability to market shellfish or shellfish products in interstate commerce because of pollution. Economic injury resulting from periodic closures of shellfish beds in Mobile Bay prompted such a conference, "In the Matter of Pollution of Navigable Waters of Mobile Bay and its Tributaries", held in Mobile, Alabama, on January 27-28, 1970.

Information and data presented in the Conference documented sources of industrial and domestic wastes and their effects, particularly coliform densities, upon the bay waters. The emphasis of the Conference necessarily was directed at point sources of waste discharges and little attention was given to the environmental effects of dredging activities and practices in the bay. It was apparent that very little specific information or data concerning the effects of dredging operations in this particular body of water were available. As a result, the conferees included in their recommendations (Recommendation No. 7) that a Technical Committee, composed of representatives of the

Alabama Water Improvement Commission, the State Department of Conservation and Natural Resources, the U.S. Corps of Engineers, and the Federal Water Pollution Control Administration (now the Environmental Protection Agency) be established to analyze the dredging situation in Mobile Bay, and recommend a program for future operations.

The proceedings of the Conference were approved in March, 1971, by Mr. William Ruckelshaus, EPA Administrator, which set in motion the action necessary to implement the recommendations. Subsequently, a Technical Committee was formed in an organizational meeting on June 3, 1971, at which time the following members were named:

Agency	Members	Co-Committee Members
Corps of Engineers	COL Harry A. Griffith Chairman	E.A. Drago T.O. Gaillard
Environmental Protection Agency	John C. Nyhan	Pat Langan Billy H. Adams
Alabama Water Improvment Commission	Arthur N. Beck	Joe Crockett John Bolton
Alabama Department of Conservation & Natural Resources	William F. Anderson	Wayne Swingle Sam Spencer

The wisdom of this recommendation has been evidenced by bringing together these various agencies, having environmental responsibilities in Mobile Bay, in a simultaneous

inter-disciplinary approach to this complex problem. The Technical Committee in turn invited other organizations to assist in their effort. The Committee's objective was to analyze the dredging operations and document their effects, then formulate a program which could be recommended for future operations. Thus a concerted effort would develop a program which reflects a realistic solution by satisfying environmental guidelines both from a public health and conservation viewpoint, while, at the same time, allowing commerce to continue operation and growth.

To that end, the following organizations were invited to participate in the workings of the Committee:

South Alabama Regional Planning Commission

Marine Sciences Institute, University of Alabama

Geological Survey of Alabama

Bureau of Sport Fisheries and Wildlife

Waterways Experiment Station, Corps of Engineers

The Technical Committee has been in operation for one year and accomplishments to date have consisted of a review of existing dredging projects, discussion of future projects under consideration and a short-term field study which assessed selected areas within Mobile Bay. One of the more significant accomplishments has been the establishment

of an effective dialogue and exchange of information between the various agencies having responsibility for dredging operations.

This report presents tne environmental data and information collected by the Technical Committee in a base line field investigation of Mobile Bay conducted from October 1971 to February 1972. Data were collected at different intervals throughout this time period and field trips were scheduled to coincide with dredging activities and to avoid inclement weather.

The study was conducted by the "Working Committee', a sub-group of the Technical Committee, given the responsibility of performing the routine functions of the Committee. The 'Working Committee" is composed of representatives from the agencies named by the Conference, and representatives from the other invited agencies.

This study was designed as a preliminary investigation of the Bay for the purpose of defining and evaluating dredging related problems and thus establish a base for a more comprehensive, in-depth study. Several detailed studies, now in progress, were propagated by this initial effort and these studies are discussed later in this report.

II. SUMMARY AND CONCLUSIONS

(Conclusions of this report are based upon the completed studies only)

1. Sediment study results have revealed that contaminants in sediment at 26 of 33 sampling locations in Mobile Bay exceed the suggested EPA dredging criteria for open-water disposal. The following is a comparison of the EPA criteria with the study results:

Parameter	EPA Limits	Study Results
Volatile Solids	6.0%	38 of 70 observations (54%) exceeded the limit
COD	5.0%	32 of 70 observations (46%) exceeded the limit
TKN	0.10%	48 of 70 observations (68%) exceeded the limit
Zinc	50 ppm	35 of 70 observations (50%) exceeded the limit
Lead	50 ppm	5 of 70 observations (7%) exceeded the limit
Mercury	1.0 ppm	1 of 50 observations exceeded the limit
Oil-Grease	0.15%	1 of 4 observations exceeded the limit

In addition to the suggested EPA criteria, sample results also showed that phosphorus ranged from 44 to 1,300 ppm, chromium varied from 4.0 to 68 ppm; copper extremes were 1.0 to 23 ppm. Pesticides, DDE and DDD, were detected

in 3 of 10 samples at concentrations ranging from 0.59 to 73 ppb while DDT was found in only 2 of 10 samples at concentrations of .73 and 330 ppb. No PCB's were detected in 10 samples analyzed.

Sediment sampling results revealed that:

a. Although clayey sediments generally contained the highest concentrations of pollutants while sandy sediments contained the lowest concentrations, sampling was not sufficient to allow prediction of the degree of contamination merely on the basis of sediment type.

b. Parameters analyzed generally appear to increase in concentration with distance from the causeway.

c. The relationship of concentration with depth varies from station to station with no discernible pattern.

d. Data from two deep core sampling stations (W-6 and W-7) are inadequate to conclude the relationship between parameter concentrations and sediment age (depth).

2. The short term water quality study of open-water spoil disposal around the shell dredging in Mobile Bay indicates that heavy metals resuspended during dredging are

retained in suspended residue and not returned to the aqueous solution. It is the opinion of the committee that data available to date do not warrant the cessation of dredging projects, but the environmental effects of dredging on water quality and aquatic life are inconclusive from this limited study. Studies presently being conducted in Mobile Bay by members of the committee and organizations cooperating with the technical committee should supplement available information and permit an assessment of the individual and accumulative environmental effects of dredging on Mobile Bay.

3. Investigations by the working committee revealed that the national dredging criteria of EPA may have been established without factual data as to water quality or biological considerations. Although the biological significance of the transfer mechanisms of sediment contaminants to water and/or aquatic organisms has nationwide application, regional differences in water quality exist from area to area because of differences in geological, physical, chemical, and biological characteristics. The development of effective dredging criteria must be accomplished on a regional basis through the cooperation and assistance of Federal and State agencies.

4. Sediment determination, using different analytical methods, produces incomparable results. Analytical sediment methods described in the Chemistry Laboratory Manual Bottom Sediments, EPA, December 1969 and 1971, are presently approved by EPA.

III. RECOMMENDATIONS

1. The Environmental Protection Agency re-evaluate its dredging criteria for open-water disposal. During re-evaluation it is further recommended that:
   a. necessary studies be made to determine the biological significance of the transfer mechanisms of contaminants in sediment to water and/or aquatic organisms. This work, having nationwide application, should be funded and/or performed at the national level by appropriate agencies.
   b. in view of differing water quality conditions which may exist in geological, physical, chemical and biological characteristics from area to area, that dredging criteria be established on a geographic basis in cooperation with the regional Federal and State agencies.
   c. consideration be given to evaluating additional parameters not presently included in the EPA criteria.
2. A moratorium should not be declared on all types of dredging in Mobile Bay, but the individual and accumulative environmental effects of each dredging project should be considered on a case by case basis.

3. This Committee should not make any decisions on the environmental effects of dredging until the Committee has evaluated results of on-going studies.
4. Sediment should be analyzed by methods approved by EPA.

IV. DESCRIPTION OF STUDY AREA

The Mobile River is formed by the junction of the Alabama and Tombigbee Rivers, approximately forty miles north of Mobile, Alabama. The river flows in a southerly direction for some forty-five river miles before entering Mobile Bay. Mobile Bay is a relatively large shallow bay with an overall area of approximately 419 square miles with an average depth of 9.8 feet.

The Mobile River-Mobile Bay drainage basin comprises approximately 2,060 square miles of Mobile and Baldwin Counties. Although the drainage area defined by these limits is relatively small, waters flowing into this basin drain approximately 64 per cent of Alabama as well as portions of Georgia, Mississippi and Tennessee, giving a total of 44,170 square miles draining into Mobile Bay.

Due to the large drainage area and unregulated flood flows on the Alabama and Tombigbee River, the flow into Mobile Bay through the Mobile River system varies widely, ranging from 10,000 cfs during the dry, fall months to more than 532,000 cfs during the spring floods.

Flow in the Mobile River is influenced by natural diversion to the Tensaw River below Mt. Vernon. It is estimated that approximately 60 per cent of the flow in

the Mobile River is diverted to the Tensaw during periods of low to moderate flows and 50% diverted during high flows.

All waters of Mobile Bay and the Mobile River, as well as all or portions of their tributaries, are influenced by tidal fluctuations. Mobile Bay has one tide daily, with each tidal cycle taking approximately 25 hours. Tidal fluctuations vary from less than one foot during neap tides to two and one-half feet during spring tides.

Major tributaries of the Mobile River include Three Mile Creek, Chickasaw Creek and Bayou Sara. Major tributaries entering Mobile Bay, other than the Mobile River, include the Tensaw River, Spanish River, Apalachee River, Blakely River, Dog River, Fowl River and Fish River. The Spanish, Apalachee and Blakely Rivers are straits originating in the Tensaw River.

The principal cities within the Mobile Basin are Mobile, Prichard, Chickasaw and Fairhope. At the present time, approximately 320,000 people reside in the immediate Mobile metropolitan area. Projections indicate that population will increase to 390,000 by 1975. The upper portion of the Bay and the Mobile River are presently heavily industrialized. However, there are still large tracts of undeveloped land, and expansion of present industries and location of new industries are anticipated.

V. STUDY PROGRAM

A. EPA Guidelines

The Southeast Region of EPA uses as a guide its published "Water Quality Considerations For Construction and Dredging Operations, Revised April, 1971." Contained in the publication are specific numerical values for certain parameters which are considered the maximum acceptable limit for open-water disposal. The parameters for which limits have been established are: Volatile Solids, COD, TKN, Oil-Grease, Mercury, Lead and Zinc.

B. Study Objectives

1. Characterize bottom sediments in terms of various pollutional parameters at specific locations in Mobile Bay.

   a. Resurvey nine stations previously established by the Alabama Department of Conservation and Natural Resources:
   In October of 1970, Dr. J. M. Lawrence, Agriculture Experiment Station, Auburn University, Auburn, Alabama, analyzed sediment samples for heavy metals from nine stations selected by the Alabama Department of Conservation & Natural

Resources. These stations were generally located at the mouths of the major tributaries to the Bay with only two of the stations being located in open-water areas of the Bay. Results of analyses for these stations suggested that most of the stations contained excessive concentrations of heavy metals. In order to verify these data and because the established locations of the stations fit well into the sampling network designed by the Committee, the stations were resampled. These nine stations are designated "S" in the report.

b. Survey additional sampling stations in the bay so as to provide for a network of stations including tributary streams peripheral to the bay and a grid system across the open-water area of the bay:
The Committee selected additional stations in tributary streams, and established open-water bay stations on the basis of: sediment type defined by Ryan, 1969; areas of dredging; and, conformancy to a 3-mile grid system. The grid system was designed

to provide an orderly approach so that future studies may utilize the network in supplying additional data to a master plan. Stations established by the Committee are designated "W" in this report.

2. Attempt to establish background pollutional levels in Bay sediments and core borings. Efforts to establish natural background levels were accomplished by taking deep core borings at the following stations:

   W_3 Spanish River near Mobile River

   W_6 Upper end of Chacaloochee Bay

   W_7 Bay Minette Basin

   Additionally, sediment cores were taken in two areas presumed to be free from any pollution sources. These two stations are:

   W_{19} Upper end of Fish River

   W_{20} Alligator Lake, Dauphin Island

3. Survey water quality aspects of typical dredging projects in the Bay.

   a. Open-water disposal; maintenance dredging in lower ship channel.

b. Diked-land disposal; Mobile River maintenance dredging.

c. New channel construction in an undisturbed area of the bay; channel construction in D'Olive Bay by the Diamondhead Corporation.

d. Buried reef shell dredging; the Radcliff Materials operation.

VI. RESURVEY OF STATE SAMPLE STATIONS

The locations of the nine sediment samples collected by the Department of Conservation and Natural Resources in October 1970 are shown on Figure 1. Metal analyses conducted by Dr. J. M. Lawrence on these samples are shown in Table 1. Of the metals analyzed, only three, mercury, lead and zinc have EPA Guidelines for open-water disposal. The results given by Dr. Lawrence for mercury, however, are in unrelated units, and therefore only lead and zinc can be compared with the guidelines. Concentration of zinc at most of the stations exceeded EPA guideline criteria (50 ppm). Concentration of lead did not exceed the guideline level (50 ppm) at any location sampled. Concentrations of other metals for which there are no EPA guidelines suggested to the Committee that many of the stations were contaminated. The Department of Conservation also surveyed 63 other locations spread throughout the State of Alabama and concentrations of zinc at these stations were likewise excessive. These study data are not contained in this report but were used as reference in evaluation of contaminant concentrations in areas of no known discharges of pollutional materials.

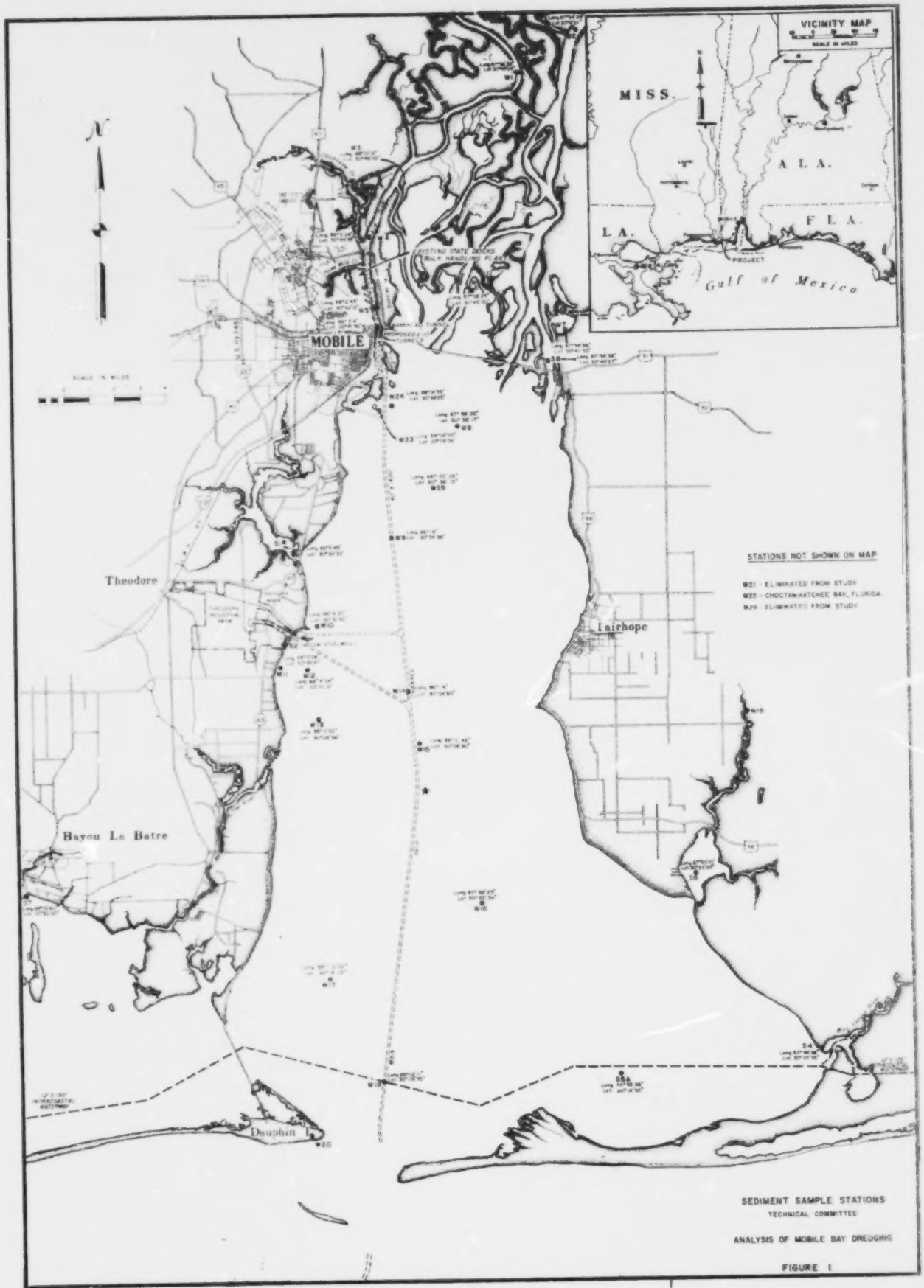

VICINITY MAP
MISS.
ALA.
LA.
FLA.
Gulf of Mexico
PROJECT
N
MOBILE
Theodore
Bayou La Batre
Fairhope
Dauphin I.
STATIONS NOT SHOWN ON MAP
W21 - ELIMINATED FROM STUDY
W22 - CHOCTAWHATCHEE BAY, FLORIDA
W24 - ELIMINATED FROM STUDY
SEDIMENT SAMPLE STATIONS
TECHNICAL COMMITTEE
ANALYSIS OF MOBILE BAY DREDGING

FIGURE 1

TABLE 1. Concentrations of selected elements in bottom sediments of Mobile Bay and its tributaries. Concentration expressed in parts per million dry weight, except mercury.1/ October 1970. Data from J.M. Lawrence (per.comm.)

Element	Stations (See footnotes)								
	1	2	4	5	6	7	8	9	10
Calcium	135.0	55.0	205.0	225.0	130.0	275.0	165.0	41.0	975.0
Cadmium	1.9	0.6	0.8	1.1	1.1	1.1	1.1	1.5	1.8
Chromium	455	435	452.5	575.0	357.5	280.0	710.0	10.5	340.0
Cobalt	27.5	26.0	23.0	25.0	19.0	14.0	19.0	4.5	23.5
Copper	60.0	55.0	50.0	104.0	39.0	31.5	37.5	10.0	75.0
Iron	12,400	9,250	8,850	8,590	8,750	7,900	7,625	2,425	9,300
Lead	34.0	21.5	15.0	34.0	24.5	18.0	12.0	6.5	30.0
Magnesium	2,550	2,500	2,475	2,500	2,500	2,500	2,480	350	2,500
Manganese	264.0	1,425	340	1,065	250	510	800	160	1,650
Mercury	426	75	33	69	69	63	72	6	156
Molybdenum	70.0	5.0	125.0	175.0	5.0	5.0	70.0	0.0	300.0
Nickel	59.0	107.5	150.0	185.0	60.0	110	250.0	26.0	36.5
Phosphorus	1,200	2,850	2,100	1,950	2,500	2,100	1,400	750	2,450
Strontium	2.2	2.8	2.6	3.2	3.8	6.9	5.3	3.2	17.5
Zinc	205.0	207.5	116.5	310.0	172.5	152.0	63.0	39.0	317.0

1/ Mercury concentration expressed in micrograms per square foot of bottom sediment.
Stations: 1. Dog River at mouth. 2. Deer River below steel mill. 4. Bon Secour River at Bon Secour. 5.Bon Secour Bay 3 miles South of Weeks Bay. 6.Weeks Bay. 7.Bayou La Batre. 8.Blakeley River at Battleship Parkway. 9.Mobile Bay 3 miles East of Dog River. 10.Mobile River at mouth.

Results of EPA analyses performed on sediment samples taken at the "S" stations, by the Working Committee, yield differences in concentrations when compared to Lawrence's 1970 results. A comparison of the results of the two studies is shown in Table 2. There are significant differences between the two studies because different analytical procedures were followed. Different digestion procedures used prior to analyses by atomic absorption spectrophotometry resulted in considerable, although inconsistent, differences in reported concentrations of metals. The digestion method used by Lawrence (Techniques Utilized For Collecting And Analyzing Samples Of Water, Suspended Matter, Hydrosol, Plants, And Fish. J. M. Lawrence, 1971. Agri. Exper. Sta., Auburn University) is a more extensive digestive method than used by EPA, (Chemistry Laboratory Manual For Bottom Sediments. EPA, Dec. 1971). The former method, consequently, would be expected to give higher results, than does the method used by EPA.

Though concentrations differ between the two sets of samples, concentrations of zinc in bottom sediments exceeded the EPA criteria (50 ppm) in eight of nine analyses by Lawrence and six of nine analyses by EPA.

TABLE 2. Comparison of sediment analyses from Mobile Bay and tributaries. State analyses by Auburn Univ.- Oct. 1970. EPA analyses Oct. and Nov. 1971. Expressed parts per million on a dry weight basis.

Sta. No.	Location	Phosphorus			Chromium			Zinc			Lead			Copper		
		State	EPA	%Dif	State	EPA	%Dif	State	EPA	%Dif	State	EPA	%Dif	State	EPA	%Dif
S-1	Dog River	1200	189	535	455	15	2933	205	37	454	34	16	112	60	2.8	2043
S-2	Deer River	2850	412	592	435	26	1573	207.5	72	188	21.5	38	77	55	3.6	1428
S-4	Bon Secour River	2100	400	425	452.5	34	1231	116.5	68	71	15	32	113	50	8	525
S-5	Bon Secour Bay	1950	442	341	575	50	1050	310	81	283	34	32	6	104	11	845
S-6	Weeks Bay	2500	400	525	357.5	34	951	172.5	59	192	24	27	12	39	5.2	650
S-7	Bayou La Batre	2100	148	1319	280	4.8	5733	152	17	794	18	10	80	31.5	3.2	884
S-8	Blakeley River	1400	792	177	710	10	7000	63	47	34	12	24	100	37.5	3.2	1072
S-9	Mobile Bay	750	131	473	10.5	36	243	39	135	246	6.5	25	285	10	6.8	47
S-10	Mobile River	2450	625	292	340	36	844	317	186	70	30	48	60	75	16	369
Average % of Difference				520			2395			259			94			873

VII. SEDIMENT SAMPLING PROGRAM

A. General

Core samples were collected at 33 stations in the Mobile Bay area, including nine of the ten stations selected in earlier sampling by the State Department of Conservation and Natural Resources, designated by the letter 'S'. Twenty-one are designated by the letter 'W', one is identified as D'Olive Bay and two as Radcliff shell dredge stations. Table 3 containing the results of the analyses also describes the location of each sampling station. Geographical locations of the sampling stations are shown on Figure 1.

Seventeen stations were located in the Bay proper and may be categorized as follows:

Open water: W-8, 10, 11, 12, 13, 16, 17; S-5A, 9; D'Olive Bay; Radcliff stations(2)

Spoil or channel: W-9, 14, 15, 23, 25

Sixteen stations were located either in the delta, tributary streams, or adjacent waters:

Delta: W-1, 2, 3, 4, 5, 6, 7; S-8, 10

Tributary streams: S-1, 2, 4, 6; W-19

Adjacent waters: S-7 and W-20

The depth of the cores, as well as the number of samples from each core, varied from station to station. Up to three samples, surface, middle, and bottom, were taken from each core. Core

TABLE 3. Mobile Bay Sediment Data - 1971.

Results expressed on dry weight basis.

Station No.	Location	Depth	%Vol. Solids	COD (mg/kg)	%Org. C	TKN (mg/kg)	Percent Oxidizable Nitrogen	P (mg/kg)	Cr (mg/kg)	Hg (mg/kg)	Zn (mg/kg)	Pb (mg/kg)	Cu (mg/kg)
W-1	Mobile Riv.@ RR Br.	Surface	6.45	43,100	1.6	1,300	0.13	838	27	0.17	292	26	11
W-2	Tensaw Riv.@ RR Br.	Surface	7.80	49,900	1.9	1,850	0.18	569	30	0.19	116	24	6
W-3	Spanish Riv. Near	Surface	5.42	33,000	1.2	1,200	0.12	769	24	0.23	218	29	2.8
	Mobile Riv.	11 Ft.	--	--	--	--	--	--	--	--	--	--	--
W-4	Mobile Riv. Near Surface Chickasaw Cr.	Surface	7.42	54,600	2.0	1,480	0.15	650	31	0.45	184	47	3.2
W-5	Mobile Riv.@ State Docks	Surface	12.04	72,600	2.7	2,200	0.22	75	45	--	223	86	16
W-6	Chacatoochee Bay@	Surface	2.6	22,600	0.85	650	0.06	150	10	0.05	24	22	1.2
	Upper End	12.7 Ft.	2.6	28,500	1.1	600	0.06	68	8	0.12	29	12	1.6
W-7	Bay Minette Bay	Surface	7.4	51,300	1.9	1,880	0.19	560	26	0.08	58	26	8.4
		8.7 Ft.	2.66	29,900	1.1	600	0.06	78	12	0.58	33	16	1.2
		14.8 Ft.	2.02	32,600	1.2	400	0.04	64	8	0.57	25	4	2.4
W-8	Mobile Bay&Upper	Surface	9.55	74,000	2.8	1,380	0.14	312	50	0.19	72	31	4.8
	Middle	35 In.	5.13	61,100	2.3	1,120	0.11	162	16	0.06	44	19	3.2
		70 In.	4.71	56,400	2.1	1,100	0.11	191	16	0.06	44	18	3.2
W-9	Mobile Bay - 100	Surface	5.48	63,300	2.4	1,200	0.12	170	17	--	49	30	3.6
	Yds.SE of Naviga-	9.77 m	4.48	11,200	0.42	750	0.08	681	21	0.07	27	22	4.4
	tion Light #36	12.25 m	4.31	34,200	1.3	650	0.06	406	16	--	42	16	2.8
W-10	Mobile Bay Near												
	TheodoreShipChan.	Surface	0.91	6,620	0.25	450	0.04	79	60	0.05	18	8	1.6
		16 In.	6.61	31,700	1.2	900	0.09	179	24	0.06	54	22	5.2
		33 In.	0.96	4,680	0.17	320	0.03	108	4.8	0.04	18	12	2.8
W-11.	Mobile Bay-N of	Surface	0.95	7,840	0.29	250	0.02	88	6.4	0.04	10	10	2.0
	Belle Fontaine	28 In.	0.97	7,920	0.30	420	0.04	74	6.0	--	17	14	2.4
W-12	Mobile Bay-NE of	Surface	6.40	42,700	1.6	1,200	0.12	331	31	--	84	26	6.0
	Belle Fontaine	29 In.	2.83	32,700	1.2	1,050	0.10	188	24	0.07	42	18	3.2
		58 In.	2.97	29,900	1.1	780	0.08	1,210	10	0.23	34	15	2.0
W-13	Mobile Bay-NE of	Surface	11.01	59,700	2.2	2,150	0.22	436	68	0.08	153	37	12
	Fowl Riv. Pt.	30 In.	5.97	48,200	1.8	1,250	0.12	218	28	0.08	50	16	3.6
		60 In.	5.44	41,900	1.6	880	0.09	221	18	0.05	40	32	2.0
W-14	Mobile Bay-Ship	Surface	10.53	52,200	1.9	1,980	0.20	592	46	--	125	57	23
	Chan. E NE of Belle Fontaine												
W-15	MobileBay - E of	Surface	9.30	59,500	2.2	1,500	0.15	380	36	0.09	70	44	6.8
	Ship Chan. W of	36 In.	8.00	64,300	2.4	1,400	0.14	275	32	0.08	70	29	4.8
	Point Clear	72 In.	7.81	68,100	2.5	1,420	0.14	275	28	0.08	64	26	4.8

NOTE: 1) Underlining indicates EPA Guidelines exceeded.
2) mg/kg=ppm; ug/kg=ppb

TABLE 3 CONTINUED.

Results expressed on dry weight basis.

Station No.	Location	Depth	%Vol. Solids	COD (mg/kg)	%Org. C	TKN (mg/kg)	Percent Oxidizable Nitrogen	P (mg/kg)	Cr (mg/kg)	Hg (mg/kg)	Zn (mg/kg)	Pb (mg/kg)	Cu (mg/kg)
W-16	Mobile Bay-W of Fish Riv. Pt.	Surface	11.24	47,200	1.8	1,620	0.16	446	52	--	88	32	11
		28 In.	9.29	79,200	2.9	1,650	0.16	296	30	0.65	69	25	6.8
		55 In.	10.33	72,200	2.7	1,450	0.14	275	30	0.40	79	34	4.8
W-17	Mobile Bay-N of Dauphin Island	Surface	--	--	--	--	--	--	--	--	--	--	--
		29 In.	6.97	40,100	1.5	1,450	0.14	706	42	--	92	34	11
		58 In.	7.29	49,100	1.8	1,480	0.15	1,300	42	0.16	79	32	10
W-19	Fish River	Surface	13.81	170,000	6.4	4,300	0.45	452	26	--	33	42	6.4
		21 In.	9.68	114,000	4.3	1,880	0.19	281	20	0.08	24	27	6.8
		42 In.	8.14	88,900	3.3	1,480	0.15	169	18	0.05	23	19	6.0
W-20	Alligator Lake	Surface	2.42	22,300	0.83	700	0.07	183	4	--	20	6	1
W-23	Mobile Bay-SE Corner of McDuffieIs.	Surface	0.81	3,760	0.14	480	0.05	130	15	0.05	37	8.8	2
		19 In.	4.04	38,500	1.4	580	0.06	184	18	0.09	48	16	4.4
	W of Ship Chan.	39 In.	1.96	14,200	0.53	550	0.06	44	15	0.06	26	14	2.4
W-25	Mobile Bay-SE Corner of McDuffieIs.	Surface	0.59	2,750	0.1	320	0.03	49	6	0.05	22	11	1.6
		19 In.	6.44	30,400	1.1	1,200	0.12	425	28	--	53	25	6.8
	E of Ship Chan.	38 In.	5.48	27,800	1.0	1,080	0.11	370	24	0.06	58	20	5.2
S-1	Dog Riv.-300 Yds.	Surface	4.16	47,600	1.8	2,150	0.22	189	15	0.06	37	16	2.8
	Upstream From Br.	18 In.	4.37	46,500	1.7	2,600	0.26	217	18	0.07	44	73	2.4
S-2	Deer River	Surface	11.07	136,000	5.1	2,250	0.22	412	26	1.18	72	39	3.6
S-4	Bon Secour River	Surface	11.77	87,700	3.3	3,750	0.38	400	34	0.09	68	32	8
		21 In.	10.65	85,600	3.2	4,200	0.42	390	36	--	69	45	8.4
		42 In.	11.57	81,000	3.0	2,250	0.22	288	49	0.11	84	36	6.4
S-5A	Bon Secour Bay	Surface	11.70	52,200	2.0	1,700	0.17	442	50	0.08	81	32	11
		31 In.	8.89	70,100	2.6	1,680	0.17	294	34	0.10	65	23	8
		62 In.	7.91	64,100	2.4	1,650	0.16	312	32	0.78	60	28	5.2
S-6	Weeks Bay	Surface	9.39	85,500	3.2	1,920	0.19	400	34	--	59	27	5.2
		19 In.	8.73	68,200	2.5	1,620	0.16	181	27	--	48	26	5.6
		38 In.	7.39	78,000	2.9	1,620	0.16	271	28	0.09	47	32	3.2
S-7	Bayou La Batre	Surface	1.43	9,880	0.37	600	0.06	148	4.8	--	17	10	3.2
S-8	BlakeleyRiv.-Up-Stream Fm Br.	Surface	1.93	12,500	0.47	700	0.07	792	10	0.06	47	24	3.2
S-9	Mobile Bay-E of Dog Riv. Pt.	Surface	6.84	57,900	2.2	1,380	0.14	131	36	--	135	25	6.8
		38 In.	5.33	45,000	1.68	1,120	0.11	186	18	0.05	35	11	2.4
		76 In.	5.25	45,000	1.68	1,000	0.10	233	25	0.05	42	15	3.2
S-10	Mobile River	Surface	10.39	76,900	2.9	1,920	0.19	625	36	0.41	186	48	16
	D'Olive Bay	Surface	8.29	47,500	1.8	1,620	0.16	462	25	--	110	26	5.2
		20 In.	9.93	60,200	2.2	1,720	0.17	769	44	--	212	82	11
		40 In.	1.28	8,780	0.33	1,700	0.17	169	14	--	27	13	2
R-50	50 Ft Ahead of Radcliff Materials Shell Dredge	Surface	7.76	52,400	2.0	1,780	0.18	423	55	--	85	36	9.6
		48 In.	9.68	52,200	2.0	1,800	0.18	428	55	--	100	52	9.2
R-10	10 Ft Behind Shell Dredge	Surface	3.77	13,500	0.51	700	0.07	128	13	--	21	34	10

TABLE 3 CONCLUDED.

Station No.	Location	Depth	Grease (mg/kg)	DDE (ug/kg)	DDD (ug/kg)	DDT (ug/kg)	Other Pesticides (ug/kg)	PCB (ug/kg)
W-3	Spanish Riv. near	Surface	-----	62	73	330	ND[a]	ND
	Mobile Riv.	11 ft.	-----	ND	ND	ND	ND	ND
W-5	Mobile River @ State Docks	Surface	3,670	-----	-----	-----	-----	-----
W-6	Chacatoochee Bay @	Surface	-----	ND	ND	ND	ND	ND
	Upper End	12.7 ft	-----	ND	ND	ND	ND	ND
W-7	Bay Minette Bay	Surface	-----	0.59	1.0	ND	ND	ND
		8.7 ft	-----	ND	ND	ND	ND	ND
		14.8 ft	-----	ND	ND	ND	ND	ND
W-17	Mobile Bay N. of	Surface	90	-----	-----	-----	-----	-----
	Dauphin Island	29 in.	81	-----	-----	-----	-----	-----
		58 in.	65	-----	-----	-----	-----	-----
R-50	50 ft. ahead of Radcliff Materials	Surface	-----	1.3	2.4	0.73	ND	ND
	Shell Dredge	48 in.	-----	ND	ND	ND	ND	ND
R-10	10 ft. behind	Surface	-----	Lost	Lost	Lost	Lost	Lost
	Shell Dredge							

[a]ND - none detected
Minimum detection limit: DDE-0.20 ug/kg
DDD-0.50 ug.kg
DDT-1.0 ug/kg
PCB-6.0 ug/kg

samples were taken at considerable depth at three stations:

W-9 in the spoil pile adjacent to the ship channel to a depth of 12.25 meters below water surface, and the background stations W-6 and W-7 located in the upper delta which were 12.7 feet and 14.8 feet into the sediment, respectively.

The remaining 30 stations for which multi-depth samples were collected may be described as follows:

surface samples consisting of the top 6 inches of the core; the middle samples, depths ranging from 16-38 inches with an average of 27 inches; and the bottom sample, depths ranging from 33 inches to 76 inches and an average depth of 52 inches.

Sediment samples for all 33 cores were analyzed for the following parameters: Volatile Solids, COD, TKN, Phosphorous, Chromium, Zinc, Lead, Copper, and Mercury (Table 3).

Additionally, DDE, DDD, DDT, other pesticides, and PCB determinations were made for five of the

stations. These stations were: W-3, 6, 7, and the two shell dredging stations. Grease determinations were made for stations W-17 and W-5.

B. Core Sampling Methods

All stations were originally planned to be sampled by coring even though 'S' stations were previously dredged; to substantiate previous work -- only dredge samples would have been necessary.

All samples were not collected as originally planned because of excessive water depths (W-1, W-2, W-5, W-14, S-2, S-8, and S-10) or too hard a bottom (W-20 and S-7). The EPA core sampler cannot be used in water greater than 14 feet deep or in compacted sand. After the study began, the Corps of Engineers provided their drilling equipment to obtain delta and ship channel cores, but in the time allotted all proposed cores could not be collected. Attempts to use a "bomb" core sampler were made in the ship channel but the fast current interfered. The sample collected at W-14 is designated as a dredge sample because the core sampler did not penetrate but was dragged along the bottom.

Samples were collected in 3 phases -- from the deck of Radcliff Materials' spud-barge "Penguin" with the EPA corer, with the Corps of Engineers' drilling equipment, and from small mobile craft belonging either to EPA or the Corps of Engineers.

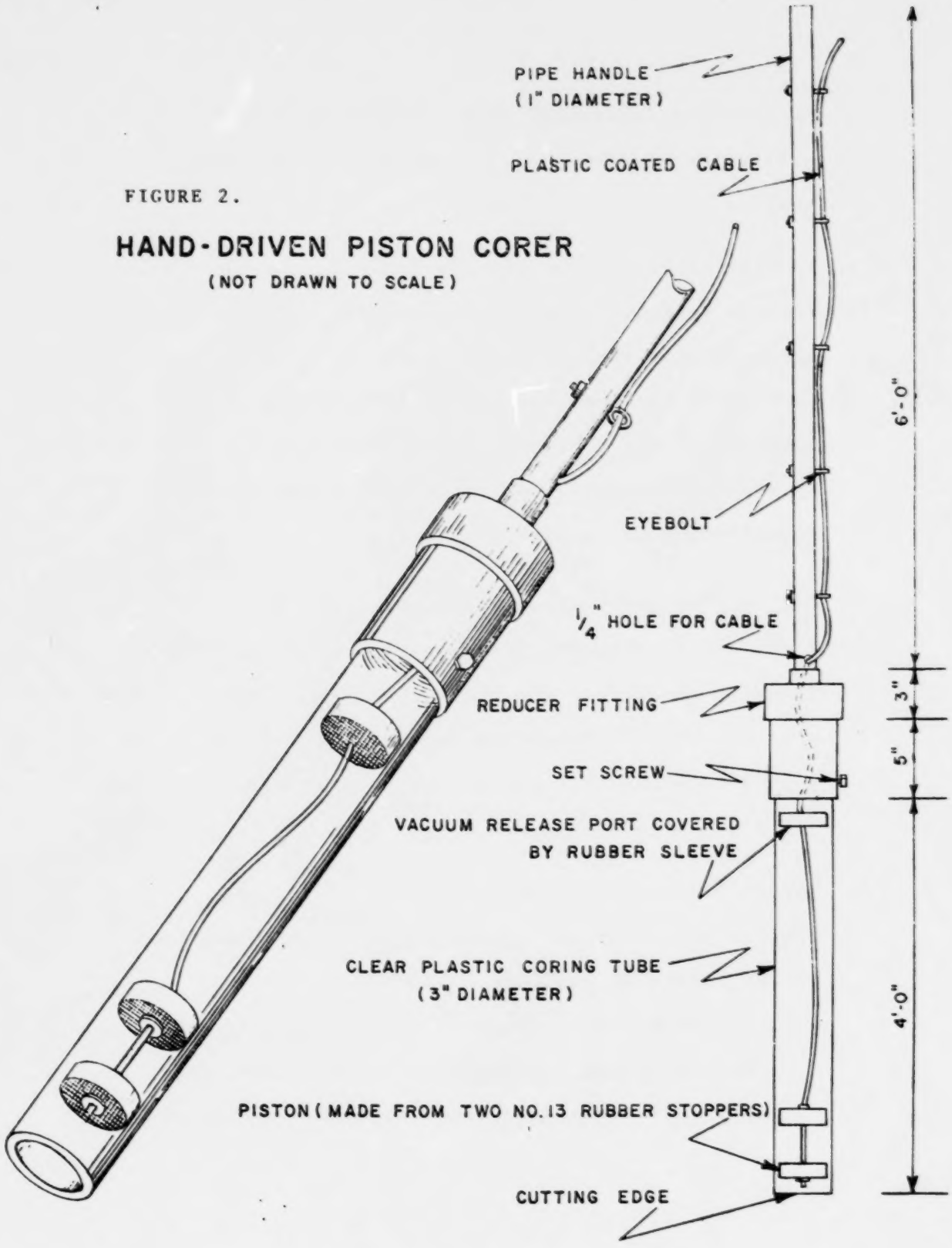
Cores obtained using the "Penguin" were collected with a 3-inch diameter cast acrylic tube (Figure 2). The tube is pushed into the bay bottom as far as possible (4'-8') by the weight of the 2 people operating it. A vacuum is created in the tube by a piston which is withdrawn as mud is forced in; upon removal from the bottom, the sediment (unless losely compacted) remains in the tube.

The surface core collected by the Corps of Engineers drilling rig was obtained by pushing a casing into the sediment and then pulling it up. Sediment stays in the casing by the combination of "teeth" in the lower end and a metal ball at the top to create a vacuum. Deeper cores were collected by jetting water down to the desired depth and then forcing the casing into the sediment.

FIGURE 2.

HAND-DRIVEN PISTON CORER

(NOT DRAWN TO SCALE)



Small boats (less than 20 feet) were used to collect dredge (Ekman) and some core (EPA corer) samples.

At time of collection the cores were measured, various sediment types were generally identified, and duplicate sample (for EPA and the Alabama Department of Conservation and Natural Resources) portions of the selected core segments were placed in separate plastic zip bags and/or glass bottles depending on the analysis required.

All samples were refrigerated until the boat returned to shore where dry ice was obtained for freezing the bags. The bottles were kept refrigerated and air shipped as soon as possible to the Southeast Water Laboratory, EPA, Athens, Georgia, for analyses.

C. Methods for Analysis of Samples

Samples were analyzed according to procedures given in the following manuals:

- Chromium, zinc, copper -- Chemistry Laboratory Manual Bottom Sediments, EPA, Dec. 1971, Page 18. Sediments were digested with concentrated

nitric acid and 30 percent hydrogen peroxide and ashed at 400°C in a muffle furnace.

- Volatile Solids, COD, Total Kjeldahl Nitrogen -- Chemistry Laboratory Manual Bottom Sediments, EPA, Dec. 1969.
- Phosphorus -- Methods for Chemical Analysis of Water and Wastes, EPA, 1971. One-tenth gram sediment was digested from sulfuric acid and ammonium persulfate.

All analytical results from the sediment samples are based on dry weight. Results of these determinations are contained in Table 3 (pp. 23-25).

D. Summary and Comparison of Results for Parameters Having Established EPA Guidelines

The EPA Guideline Criteria suggested for dredge spoil disposal to open waters were exceeded at 26 of the 33 sampling locations. A total of 70 sediment samples were collected and analyzed. A comparison of the laboratory results of these samples analyzed by parameters listed in EPA's criteria are as follows: (See also Table 4)

1. Volatile Solids: EPA limit = 6.0%
   a. 38/70 or 54% of the samples exceed the limit. 20 of these were surface samples while 18 were deeper samples.

TABLE 4. Comparison of Core Boring Results with EPA Guidelines for open water disposal

Parameter	EPA Limit	Total Samples	No.Samples Exceeding Limit	%Samples Exceeding Limit	No.Stations Exceeding at all depths	No.Stations Exceeding for at least 1 depth	Range of Values
Vol. Sol.	6.0%	70	38	54	8/21 (38%)	22/33 (67%)	0.59%-13.81%
COD	5.0%	70	32	46	7/21 (33%)	18/33 (55%)	0.28%-17.0%
TKN	0.10%	70	48	68	11/21 (52%)	25/33 (76%)	0.03%-0.45%
Zn	50ppm	70	35	50	6/21 (29%)	23/33 (70%)	68.17ppm-292ppm
Pb	50ppm	70	5	7	0	7/21 (33%)	6ppm-86ppm
Hg	1.0ppm	50	1	2	0	0	0.04ppm-1.19ppm

b. 8/21 (38%) of the multi-depth stations exceed the limit at all depths reported.

c. 22/33 (67%) stations exceed the limit for at least one depth determination.

d. The minimum value reported was 0.59% at W-25, the maximum 13.81% at W-19, and an average of 6.3% for all samples.

2. COD: EPA limit = 5.0% (50,000 mg/kg)

a. 32/70 samples, or 46% of the samples exceed the limit. Sixteen samples were surface and 16 were deeper samples.

b. 7/21 (33%) of the multi-depth stations exceed the limit at all depths reported.

c. 18/33 (55%) stations exceed the limit for at least one depth analyzed.

d. The values ranged from a low of 0.28% at W-25 to a maximum of 17% at W-19 with an average value of 4.9%

3. TKN: EPA limit = 0.10% (1,000 mg/kg)

a. 48/70 or 68% of the samples exceed the EPA limit. 23 were surface samples while the remaining 25 were deeper samples.

b. 11/21 (52%) of the multi-depth stations exceed the limit at all depths reported.

c. 25/33 (76%) stations exceed the limit for at least one depth.

d. The average value was 0.14% ranging from a minimum of 0.03% at W-11 & 25 to a maximum of 0.45% at W-19.

4. Zinc: EPA limit = 50 ppm (50 mg/kg)

a. 35/70 or 50% of the samples exceed the limit. The samples consist of 22 surface and 13 deeper samples.

b. 6/21 (29%) of the multi-depth stations exceed the limit at all depths reported.

c. 23/33 (70%) stations exceed the limit for at least one depth.

d. The average value was 68 ppm with a minimum of 10 ppm at W-11 and a maximum of 292 ppm at W-1.

5. Lead: EPA limit = 50 ppm (50 mg/kg)

a. 5/70 samples or 7% exceed the limit. 2 are surface samples and 3 are deeper samples.

b. No stations exceed the limit at all depths reported.

c. 7/21 (33%) of the multi-depth stations exceed the limit for at least one depth.

d. The average concentration was 27 ppm with a range of 6 ppm at W-20 and 86 ppm at W-5.

6. Mercury: EPA limit = 1.0 ppm (1.0 mg/kg)

a. Only one of 50 determinations exceeds the limit.

b. The average value was 0.18 ppm with a range from less than 0.04 ppm to 1.19 ppm at S-2.

7. Oil-Grease: EPA limit = 0.15% (1,500 mg/kg)

a. Results are available on only 2 stations, W-17 at three depths and W-5 at the surface. The sample at W-5 exceeds the limit while the other three values are well below the limit.

E. Summary of Results for Other Parameters Determined

1. Phosphorous: Of 70 samples, the average value was 340 ppm. The values ranged from a minimum of 44 ppm at W-23 to a maximum of 1,300 ppm at W-17.

2. Chromium: Of 70 samples, the average value was 26.7 ppm with a range of 4.0 ppm at W-20 to 68 ppm at W-13.

3. Copper: The average concentration was 5.6 ppm of the 70 samples with a range of less than 1.0 ppm at W-20 to a maximum of 23 ppm at W-14.

4. Pesticides and PCB's:

a. DDE was detected in 3 of 10 samples, all of which were surface samples. The maximum value was 62 ppb and the minimum was 0.59 ppb.

b. DDD was detected in 3 of 10 samples, all of which were surface samples. The maximum value was 73 ppb while the minimum was 1.0 ppb.

c. DDT was detected in 2 of 10 samples, both of which were surface samples. A low of 0.73 ppb was found while the maximum value was 330 ppb.

d. The scan categorized as 'Other Pesticides' revealed insignificant peaks.

e. There were no PCB's detected in the 10 samples analyzed.

F. Discussion of Results

1. Relationship of Sediment Type to Concentration of Pollutants

Recognizing that concentrations of pollutional materials in Mobile Bay sediments are, among other complex relationships characteristic of

the Bay, related to sediment type, an effort was made to determine the relative distribution of pollutants in bottom sediments by sediment type defined by the work of Ryan, 1969. (Figure 3) Obviously, a defined relationship would enable one to predict potentially polluted areas in the Bay.

Five major sediment types were sampled in Mobile Bay: clay, silty clay, clayey silt, silty sand, and sand. A total of 14 stations were located in the bay proper (Figure 1). Station W-17 is not considered because of incomplete data.

Sand: W-10, 11

Silty-Sand: W-23, 25

Clayey-Silt: W-8, 9, 12; S-9

Silty-Clay: W-13, 14, 15, 16, 17

Clay: S-5A

The following general observations can be made for those stations which are located in areas having an identifiable sediment type. (See also Tables 5 and 6.) Generally, these stations are located south of the causeway. Inasmuch as

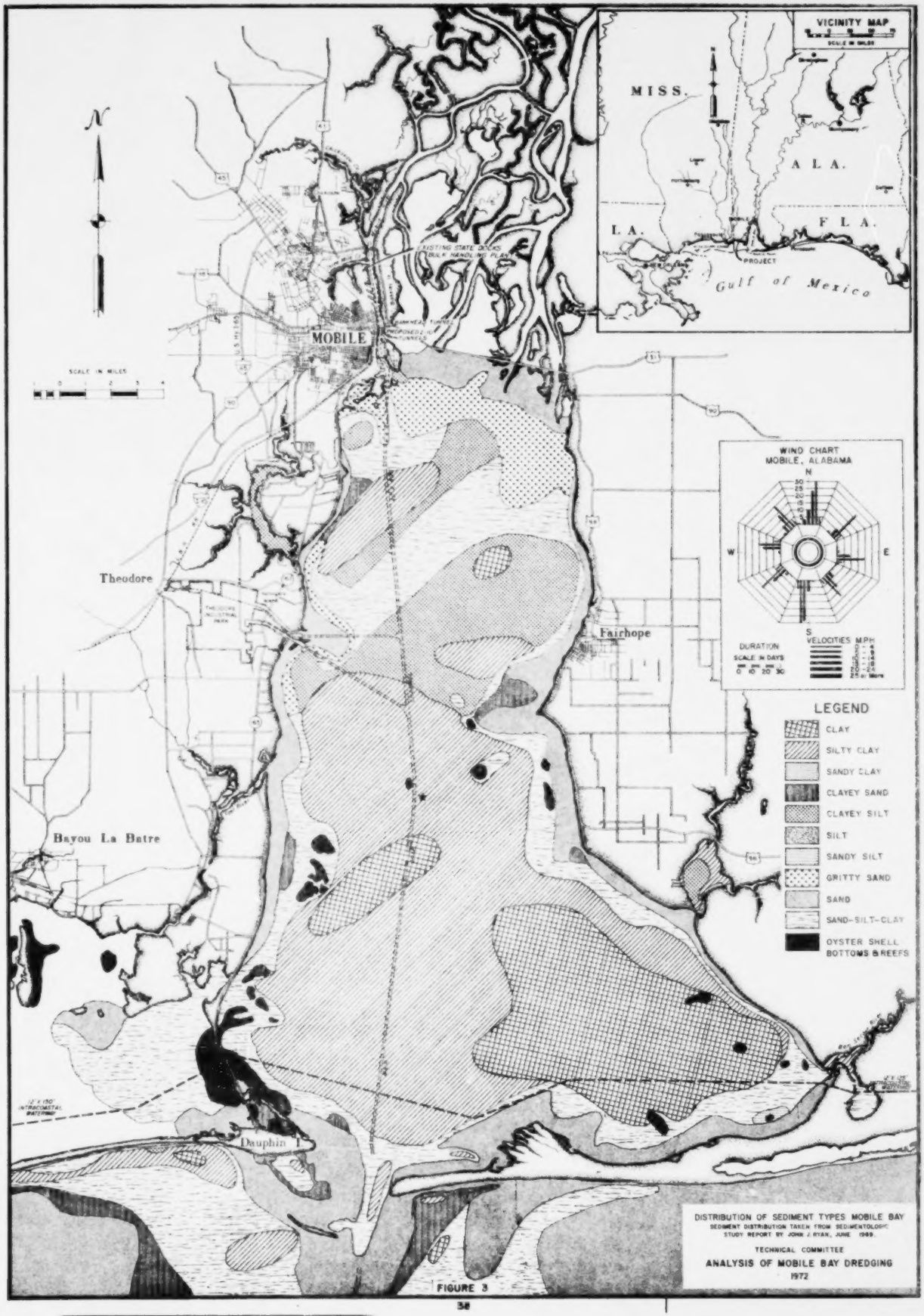

VICINITY MAP
MISS.
ALA.
LA.
FLA.
Gulf of Mexico
PROJECT
N
SCALE IN MILES
MOBILE
Theodore
Bayou La Batre
Fairhope
Dauphin I.
WIND CHART
MOBILE, ALABAMA
N
W
E
S
DURATION
SCALE IN DAYS
0 10 20 30
VELOCITIES M.P.H.
LEGEND
CLAY
SILTY CLAY
SANDY CLAY
CLAYEY SAND
CLAYEY SILT
SILT
SANDY SILT
GRITTY SAND
SAND
SAND-SILT-CLAY
OYSTER SHELL BOTTOMS & REEFS
DISTRIBUTION OF SEDIMENT TYPES MOBILE BAY
SEDIMENT DISTRIBUTION TAKEN FROM SEDIMENTOLOGIC STUDY REPORT BY JOHN J. RYAN, JUNE 1969.
TECHNICAL COMMITTEE
ANALYSIS OF MOBILE BAY DREDGING
1972

FIGURE 3

STATIONS SOUTH OF CAUSEWAY GROUPED BY SEDIMENT TYPE
(SURFACE SAMPLES ONLY)
TABLE NO. 5

SEDIMENT TYPE	STATION NO.	PARAMETER								
		mg/kg (ppm)						%		
		Cu	Cr	P	Zn	Pb	Hg	COD	TKN	VOL. SOL.
Sand	W-10	1.6*	60°°	79**	18**	8*	0.05**	0.7**	0.05**	0.91
	W-11	2.0**	6.4**	88	10*	10	0.04*	0.8	0.03*	0.95
Silty-Sand	W-23	2.0**	15	130	37	8.8**	0.05**	3.8	0.05**	0.81**
	W-25	1.6*	6*	49*	22	11	0.05**	0.28*	0.03*	0.59*
Clayey-Silt	W-8	4.8	50	312	72	31	0.19°	7.4°	0.14	9.55
	W-9	3.9	17	170	49	30	0.07	6.3°°	0.12	5.48
	W-12	6.0	31	331	84	26		4.3	0.12	6.40
	S-9	6.8	36	131	135°°	25		5.8	0.14	6.84
Silty-Clay	W-13	12.0°°	68°	436	153°	37	0.08	6.0	0.22°	11.01
	W-14	23.0°	46	592°	125	57°		5.2	0.20°°	10.53
	W-15	6.8	36	380	70	44°°	0.09°°	6.0	0.15	9.30
	W-16	11.0	52	446°°	88	32		4.7	0.16	11.24°°
Clay	S-5A	11.0	50	442	81	32	0.08	5.2	0.17	11.70°

*lowest °highest
**2nd lowest °°2nd highest

TABLE 6. Bay Stations in order of total weighted rank* for eight parameters (Vol. Sol., COD, TKN, P, Cr, Zn, Pb, Cu) measured at the mud surface. Stations are given in order of decreasing contamination, i.e. Rank 1 - most contaminated, Rank 13 - least contaminated.

RANK	WEIGHTED RANK	STATION	SEDIMENT TYPE
1	1.8657	W-14	silty-clay
2	1.9464	W-13	silty-clay
3	2.7811	S-5A	clay
4	2.8118	W-16	silty-clay
5	3.3879	W-15	silty-clay
6	3.6498	W-8	clayey-silt
7	4.1046	S-9	clayey-silt
8	4.6322	W-12	clayey-silt
9	5.0981	W-9	clayey-silt
10	6.6476	W-23	silty-sand
11	6.6571	W-10	sand
12	7.3312	W-11	sand
13	7.4844	W-25	silty-sand

*Stations were ranked for each parameter in decreasing order of concentration. The total weighted value for each station is the sum of the quotients obtained by dividing the rank for each parameter by the total number of ranks for that parameter.

Ryan's work dealt only in identification of the Bay bottom sediments, these observations are for surface samples only.

a. The concentrations for all parameters analyzed are generally higher in the clay, silty-clays and clayey-silts.

b. The sand and silty-sand bottom contained the lowest concentrations for all contaminants tested.

c. As indicated above, other complex relationships influence the disposition of pollutional materials in the Bay; however, the study data indicates that the pollutants appear to have a greater affinity for the finer grained sediments than for the coarser grained ones. Certain of the clay minerals and organic material in the finer grained sediments have significant ion-exchange capacities and pollutants may be attracted and bound within the sediment. This property may account for the apparent higher concentration in the finer grained sediments.

No attempt was made by the Working Committee to identify and determine the relative abundance of the clay minerals in the sediments analyzed. Although this aspect is extremely important for making any definite conclusions as to the relation between sediment type and concentration of pollutants, such detailed identification and determination was beyond the scope of this study. Further, it is felt that there were not enough stations evaluated so as to predict polluted areas in the Bay merely on the basis of sediment type.

2. Other Observations

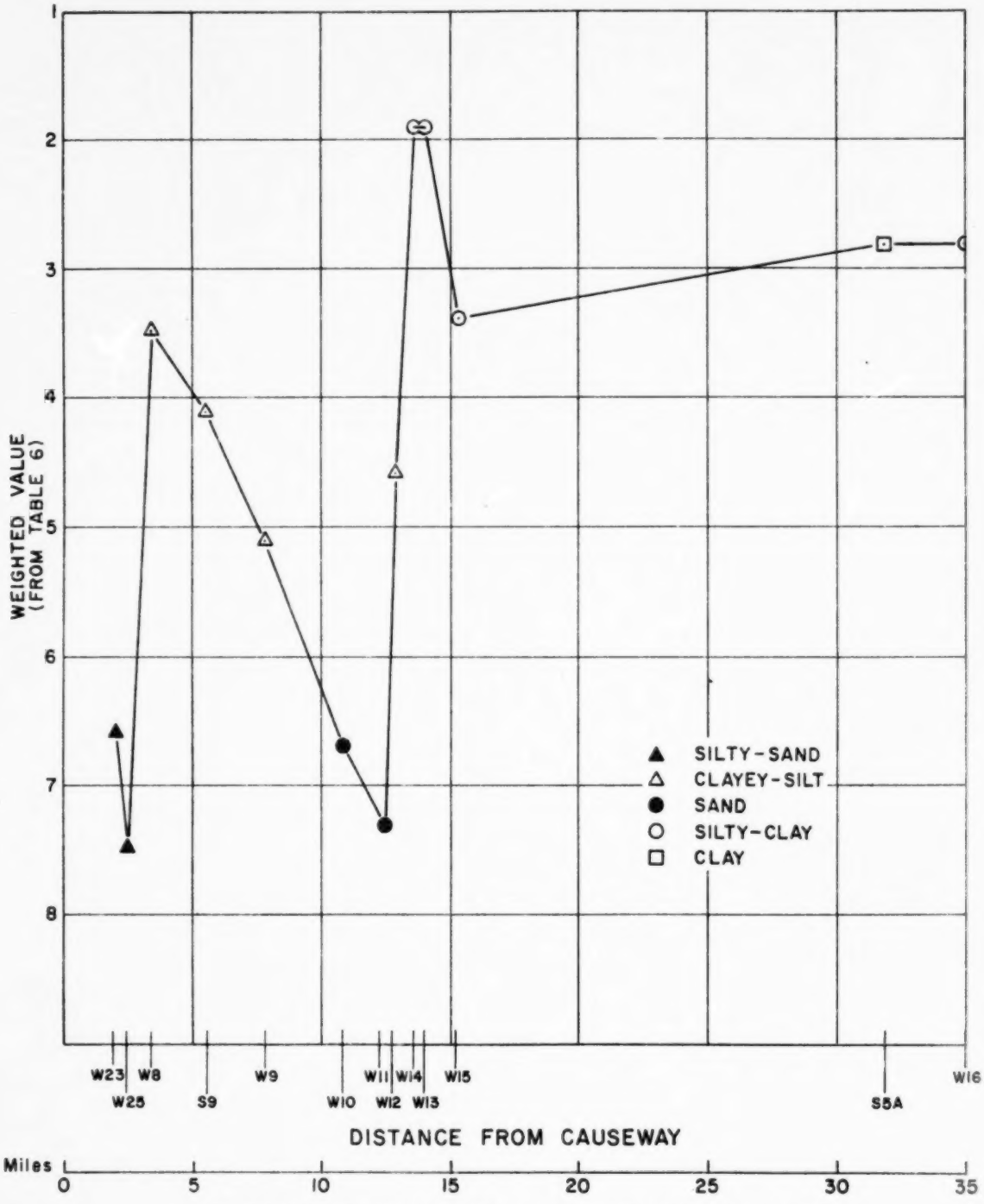
a. Considering a simple circulation pattern from the Mobile-Tensaw river system southward along the western side of the ship channel through the mouth of Mobile Bay thence re-entry thru the mouth on the flood tide to the eastern shore in a northeasterly direction (Ryan, 1969. p.80), the concentration of materials generally

appears to increase with distance from the causeway. Figure 4 demonstrates this general trend. Decreased values at stations W-10 and W-11 can be explained by a second factor, the sediment type. Both are located in sandy sediment shown to contain lower concentration of pollutant materials.

b. An evaluation of the stations excluding the two deep cores (W6-7), for which analyses were performed at more than one depth reveals that there is no consistent decrease in concentration of materials with depth. Further, the relationship of concentration with depth varies from station to station with no discernible pattern. However, most often no change is exhibited.

c. Stations W-19, in Fish River, and W-20, in Alligator Lake on Dauphin Island, were originally selected for use in establishing natural background levels of contaminants. Both were selected because there are no present pollutional sources, nor have there been in the past, in either area.

FIGURE 4



CONTAMINATION LEVELS AT BAY STATIONS AS RELATED TO DISTANCE FROM CAUSEWAY

TABLE 7. Stations in order of total weighted rank* for eight parameters (Vol. Sol., COD, TKN, P, Cr, Zn, Pb, Cu) measured at the mud surface. Stations are given in order of decreasing contamination, i.e. Rank 1 - most contaminated, Rank 32 - least contaminated. (Back-up data for Figure 4.)

RANK	STATION	WEIGHTED VALUE	RANK	STATION	WEIGHTED VALUE
1	S-10	1.6981	17	W-7	3.7871
2	W-14	1.8657	18	D'Olive	3.9577
3	W-13	1.9464	19	S-9	4.1046
4	W-5A	2.0446	20	W-3	4.3762
5	W-19	2.5103	21	W-12	4.6322
6	S-4	2.6432	22	W-9	5.0981
7	S-5A	2.7811	23	R-10	5.1953
8	W-16	2.8118	24	S-1	5.2023
9	S-2	3.0020	25	S-8	5.8609
10	R-50	3.0587	26	W-6	6.5656
11	W-4	3.1543	27	W-23	6.6476
12	W-1	3.3464	28	W-10	6.6571
13	W-15	3.3879	29	S-7	6.9723
14	S-6	3.5653	30	W-20	6.9766
15	W-2	3.6413	31	W-11	7.3312
16	W-8	3.6498	32	W-25	7.4844

*Stations were ranked for each parameter in decreasing order of concentration. The total weighted value for each station is the sum of the quotients obtained by dividing the rank for each parameter by the total number of ranks for that parameter.

However, it was determined that levels at W-20, a sandy-bottomed lake, were not applicable as background for Bay sediments because of different depositional environments.

Chemical analysis of sediments from W-19 revealed the highest levels of volatile solids, COD and TKN of any station sampled and relatively high concentrations of heavy metals. High levels of natural decaying organic materials upstream may explain the volatile solids, COD and TKN results, but there appears to be no explanation for the concentrations of the various heavy metals. This station was, therefore, not utilized in consideration of background levels.

VIII. EVALUATION OF DEEP CORE SAMPLES

An attempt was made to determine the natural concentration of pollutants in Mobile Bay by deep cores at three stations in the Mobile Delta, W-3, W-6 and W-7 (Figure 1). Of the three cores attempted in Mobile Delta only two, W-6 and W-7, were successfully completed.

Cores W-6 and W-7, 12.7 feet and 14.8 feet into the sediment, respectively, sampled sediment deposited in a delta front environment similar to that now present south of the causeway. Core W-7 is approximately two miles upstream and core W-6 approximately 2.75 miles upstream from the causeway. Ryan (1969) reported that the Mobile Delta had prograded southward one mile in 111 years. By extrapolation, it can be shown that the bottom sediments at W-7 were deposited approximately 225 years ago and at W-6 approximately 300 years ago. These figures should be considered as minimum ages for deposition. Ryan (1969) sampled oyster shells dated 5680$\pm$ 50 years ago from a subsea depth of 31 feet at Sardine Pass. This averages about 185 years per foot of sediment deposited. Using this figure the sediments at the bottom of Core W-7 were deposited 3500 years ago and those at the bottom of W-6, 4440 years ago. These last figures are probably high, but the sets

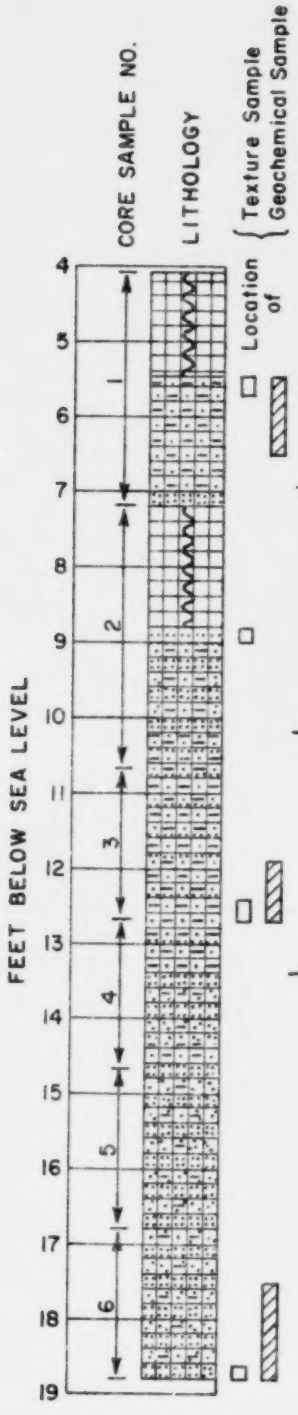
of ages give an age bracket for deposition of the sediments sampled at the base of W-6 and W-7; from several hundred to several thousand years ago, well before major industrial development of the area.

If these sediments were not contaminated either by the migration of polluted fluids or during sampling, their heavy metal concentrations should be an indication of the natural concentration of these materials. It is felt that the sampling procedures employed precluded the possibility of contamination during sample collection,and the clayey nature of the sediments makes migration of polluted fluids unlikely.

Core boring W-7 is located in Bay Minette Bay (Figure 1). The core penetrated to a total depth of 18.8 feet below sea level. Water depth at this location is 4.1 feet; a total of 14.7 feet of sediment was penetrated. The sediments consist of clayey silt at the surface and interbedded sandy clay and clayey sand at depth (Figure 5). Analyses indicate a continued decrease in concentration with depth for all parameters except copper, mercury, and chemical oxygen demand (Table 8). Copper concentration decreases overall with depth but the sample from a depth of 13 feet is lower than that from 18.8 feet.Mercury concentration significantly increases (0.04-0.43) with depth. The increase in mercury concentration is unexplainable at this time. Chemical oxygen

FIGURE 5

SEDIMENT DISTRIBUTION IN CORE BORING W7
MOBILE BAY DELTA



Clay, slightly sandy; olive gray to medium dark gray and dark yellowish orange to moderate yellowish brown; abundant organic matter and very soft in upper 2"; organic laminae in lower part.

Sand, medium to coarse grained, poorly graded, clayey; olive gray to dark gray; scattered shells.

Sand, medium grained, clayey; increase in grain size and decrease in matrix upward; olive gray to dark gray; irregular clay laminae; shell fragments concentrated at 1" and 6" below top.

Clay, sandy; with interlaminated clayey sand; olive gray to medium dark gray; massive in lower part; sand laminae irregular and lenticular; more common in middle of unit; scattered wood fragments.

Sand fine grained, clayey; olive gray to medium dark gray; massive to laminated; irregular, discontinuous clay laminae in upper 1/3 of unit; scattered shells, quartz pebbles & wood fragments.

LEGEND

- SANDY-CLAY
- CLAYEY-SAND
- SAND
- NO SAMPLE

TABLE 8. POLLUTANT CONCENTRATION AT SPECIFIC DEPTHS FROM DEEP CORES

Station & Sediment	Depth	% Moisture	% Vol. Solids	mg/kg COD	mg/kg TKN	mg/kg P	Cr	Zn	Pb	Cu	Hg
W6 mdy sand	Surface	30.3	2.60	22,600	650	150	10	24	22	1.2	<0.04
mdy sand	23-24'	28.7	2.60	28,500	600	68	8	29	12	1.6	0.09
mud	Surface	53.5	7.40	51,500	1,880	560	26	58	26	8.4	<0.04
W7 mud	12-13'	30.9	2.66	29,900	600	78	12	33	16	1.2	<0.40
mdy sand	18-19'	25.5	2.02	32,600	400	64	8	25	4	2.4	0.43
	Surface	50.81	---	-----	---	---	--	--	--	---	0.22
W4	Middle	47.11	---	-----	---	---	--	--	--	---	<0.04
	Bottom	42.28	---	-----	---	---	--	--	--	---	0.06

demand increases with depth due to the reducing conditions normally present in sediments at depth.

Core boring W-6 is located in a man-made canal between the Tensaw River and the upper part of Chacaloochee Bay (Figure 1). The core penetrated to a total depth of 23.9 feet below sea level. Water depth is 11.2 feet, leaving a total of 12.7 feet of sediment sampled. The sediments consisted of interbedded clayey sand and clayey silt (Figure 6). Some parameters, P, Cr, Pb, TKN, decrease with depth while others, Zn, Cu, Hg, increase (Table 8).

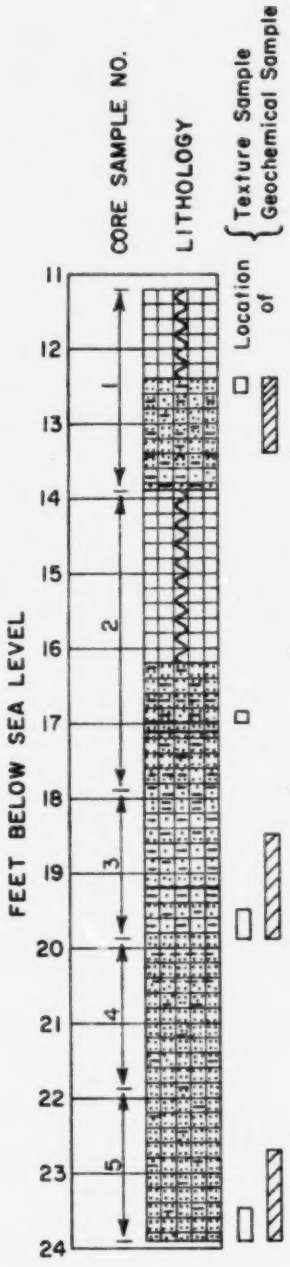
An additional core, W-4, was taken in Mobile River near the mouth of Chickasaw Creek. A total of 16 feet of sandy clay was penetrated. Mercury was the only parameter analyzed and it shows a significant decrease in depth (Table 8).

Results of analyses for W-7 and W-4 indicate a decrease in heavy metal concentration with depth, and hence, with increasing time before the present. At W-7, sediment type, clay at the surface and clayey sand at depth may account for part of the decrease, but probably not for all of the decrease. From these data,indications are that the natural concentrations of pollutants in Mobile Bay are less than that now present. Conversely, however, the data for W-6 does not bear out such an indication.

Data available from deep cores W-6 and W-7 are inadequate to draw any conclusions concerning the relationship between

FIGURE 6

SEDIMENT DISTRIBUTION IN CORE BORING W6
MOBILE BAY DELTA



Sand, fine grained, clayey; olive gray to medium dark gray; irregular mud laminae; more clayey toward top.

Clay, sandy; with interlaminated clayey fine sand; olive gray to medium dark gray; sand laminae irregular and lenticular; scattered plant fragments.

Sand, fine grained, clayey; with interlaminated clay; olive gray to medium dark gray; clay laminae up to 1/2" thick; more finely laminated with laminae not as distinct in upper part; carbonaceous laminae near middle of unit.

Clay, sandy; with interlaminated clayey fine grained sand; medium dark gray to olive gray; bedded plant fragment laminae near middle; more sandy above plant laminae; scattered shell fragments in upper part.

Sand, fine grained, clayey; light olive gray and medium dark gray; massive, with interlaminated clay at top; scattered shell and plant fragments.

LEGEND

- SANDY-CLAY
- CLAYEY-SAND
- SAND
- CARBONACEOUS
- NO SAMPLE

age (depth) of sediment and concentration of pollutant materials. Inconsistencies between the two cores, further, make it impossible to make even a general statement of a trend of either increase or decrease in concentrations with age.

Additional deep core sampling data are necessary to determine natural background levels for Mobile Bay and its tributaries.

IX. ON-GOING STUDIES: WATER-QUALITY ASPECTS OF TYPICAL DREDGING PROJECTS IN MOBILE BAY

The survey of typical dredging operations conducted in Mobile Bay was not designed to be comprehensive but intended to be only in sufficient detail to make broad assessment of the environmental effects of each type of operation.

The four projects chosen to be investigated are:

- Open-water disposal, Lower Ship Channel Maintenance Dredging
- Diked-Land Disposal - Mobile River Channel Maintenance Dredging
- Channel Construction in an undisturbed area of the bay, Channel construction in D'Olive Bay by the Diamondhead Corporation
- Buried-reef shell dredging- Radcliff Materials operations

A. Open-Water Disposal, Lower Mobile Bay Ship Channel

The Working Committee was unable to make a field survey of this operation because dredging was completed earlier than anticipated. The Alabama Marine Resources Laboratory, however, collected samples around the dredge, *The Orleans*, before maintenance was completed. Another dredge,

The Arkansas, began maintenance dredging using open-water disposal in the Bon Secour section of the Gulf-Intracoastal Waterway shortly thereafter and the Alabama Marine Resources Laboratory surveyed this operation also. The samples collected on both operations are still in the process of being analyzed in the laboratory and it will be several months before the results are available. The Technical Committee is participating in this effort by furnishing EPA and Corps of Engineers laboratories for the chemical analyses and participating with the Marine Resources Laboratory in the data analyses.

Samples collected will demonstrate the dispersal characteristics of suspended solids, its concentration horizontally and vertically, and the effect on the disposition of various contaminants as the sediment is removed by hydraulic dredge and disposed in open water.

The anticipated time schedule for completion of this phase of the study is shown in Table 11.

B. Diked-Land Disposal, Mobile River Maintenance Project.

The scheduling of dredging activities plagued the work of the Committee throughout its efforts to investigate the dredging operations. At the time the decision was made to study the Mobile River Channel Maintenance Project it appeared that dike construction would be completed about the time the field crews would be at work. However, completion of the dikes was delayed because of the difficult nature of the construction which necessarily had to be on an as-you-go basis. Unfortunately, the Working Committee field crews completed the investigation before the dikes were completed.

This portion of the study is important to the Committee's work, and the Waterways Experiment Station, U.S. Corps of Engineers, volunteered their field crew and laboratory to perform this study, so that this segment of the Committee's evaluations would not be lost. Because of the nationwide importance of these findings, the Waterways Experiment Station was able to make this contribution.

The study is designed to investigate the effects on water quality due to dredging and land containment of polluted sediments from Mobile River. For the purposes of this study, the following objectives are being addressed:

1. Determine the immediate effects of dredging polluted sediments on water quality.
   a. Measure the change in particulate chemical concentrations as the flow of materials passes from the inlet to the discharge end of the dredge pipe.
   b. Measure the change in dissolved chemical concentrations as the flow of material passes from the inlet to the discharge end of the dredge pipe.
2. Determine the pollutant containment efficiency of a diked land disposal area.
   a. Measure the change in particulate chemical concentrations as materials pass through the diked containment area.
   b. Measure the change in dissolved chemical concentrations as materials pass through the diked containment area.

3. Determine the particulate and dissolved chemical concentrations of materials seeping through the dike.
4. Determine the particulate and dissolved chemical concentrations of materials remaining in the dike.
5. Determine particulate and dissolved chemical reference conditions in Mobile River.
6. Determine the feasibility on an *in situ* dredge discharge sampler.
7. Determine the statistical adequacy of the sampling program (sample number and frequency).

Research Approach

Figure 7 shows the sample collection plan used for this study.

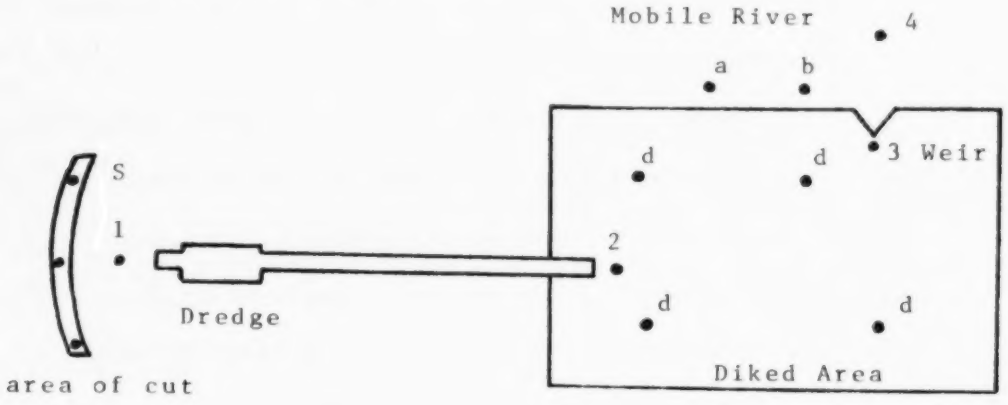


Figure 7. Sample Collection Plan

Ekman sediment samples were collected from the area of the cut immediately prior to dredging operations. Water samples (1) were collected on a daily basis in the vicinity of, but removed from the influence of, the cutterhead. These water samples were assumed to be representative of the hydraulic carrier flow. Dredge discharge samples (2) were also collected on a daily basis from the diked area discharge weir (3) and at a reference station in Mobile River (4). Water and sediment samples were also collected twice from within the diked area (d). Finally, to analyze the quality of seepage water, samples were twice collected at the toe of the dike at points "a" and "b".

All water samples were subjected to on-site analyses immediately upon collection. They were then frozen and shipped to the Waterways Experiment Station laboratories for additional analyses. All solid (sediment or spoil) samples were frozen after collection and shipped to the Waterways Experiment Station for chemical analyses. The following chemical analyses were conducted on site or are currently being conducted in the laboratory.

On Site Water Analyses

Dissolved oxygen

pH

Conductivity

Salinity

Temperature

Turbidity

Alkalinity

Color

Calcium

Magnesium

Phosphate, ortho

Nitrate

Iron

Manganese

Laboratory Water Analyses

Chemical oxygen demand*

Total Kjeldahl nitrogen

Total solids

Dissolved solids

Total volatile solids

Dissolved volatile solids

Mercury*

Zinc*

Lead*

Oil and grease

Laboratory Solid (Spoil or Sediment) Analyses

Volatile solids

Chemical oxygen demand

Total Kjeldahl nitrogen

Oil and grease

Mercury

Lead

Zinc

In addition to the above, accurate records were maintained on the amount of materials dredged and placed in the diked area during the study period.

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*Determinations made on both the dissolved and particulate phases.

The field portion of this study was conducted from 28 February to 17 March 1972. During this period, the cutterhead dredge *Blackburn* performed maintenance dredging operations on the Upper Mobile River. Approximately 167,000 cubic yards of dredged material (solids) was placed in diked spoil area number 1 -- the diked area investigated during this study. Samples were collected for 13 days, with 16 samples being collected at each of stations 1, 2, 3, and 4. When all laboratory analyses are complete, there will be approximately 2200 bits of information (data points).

At the time of this writing, all water quality analyses are complete. Analysis of the solids (sediment and spoil) is approximately 70 percent complete. All chemical analyses were completed in June with evaluation of the results expected to be completed in August. The report should be published shortly thereafter.

Table 9 shows some representative average values from each of the four locations that were sampled on a daily basis. As shown, dissolved oxygen dropped to less than 1 mg/l at the dredge discharge indicating the immediate oxygen demand associated with the bottom sediments. The dissolved oxygen was near saturation limits at the outlet weir.

As shown, pH dropped about a unit from the inlet to the discharge end of the pipe, and returned to normal study levels at the discharge weir.

Salinity values showed only small change on passing through the dredge-diked area system. The data indicate a marked salinity wedge present in Mobile River. Station 1 samples were always collected from a depth of at least 35 feet. Station 4 samples were, however, always collected

TABLE 9. Diked-Land Disposal Samples

Average Concentrations

	Station 1 Cutterhead (35')		Station 2 Dredge Discharge		Station 3 Outlet Weir		Station 4 Mobile River (20')	
	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved
DO (mg/l)	--	6	--	<1	--	7.6	--	8.7
pH	--	8	--	7	--	8.1	--	8.1
Salinity (o/oo)	--	28	--	24	--	22	--	0.6
Turbidity (JTU)	46	--	Off Scale	--	70	--	45	--
Color (units)	--	137	--	Off Scale	--	272	--	151
O-Phosphate (mg/l)	--	0.13	--	0.46	--	0	--	0.07
COD (mg/l)	54	42	96	62	107	84	34	30
TKN (mg/l)	0.47	--	18.6	--	25.0	--	0.52	--
Volatile Solids (mg/l)	2131	1976	4191	2234	4297	3315	94	83
Mercury (ug/l)	3.2	1.0	2.4	0.8	1.8	0.8	2.0	1.3
Zinc (mg/l)	0.17	0.06	0.24	0.05	0.09	0.03	0.06	0.03
Lead (mg/l)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Waterway Experiment Station

mg/l=ppm
ug/l=ppb

at the 20-foot depth. Thus, it appears the dredge was pumping primarily salt water.

Turbidity data indicate that the diked area reduced the highly turbid dredge discharge waters to an average only 24 units above river values.

The diked area was approximately 50 percent efficient in removing color imported to the water during the dredging operation.

Dredging appeared to increase the ortho-phosphate level from the inlet to the discharge. However, the value had dropped below detectable limits at the weir outlet. Further interpretation of the data is needed to explain this result.

Table 9 indicates that most (65 - 88 percent) of the chemical oxygen demand (COD) was in the dissolved phase. As shown, the COD not only increased on passing through the dredge, but also in the diked area. Although this phenomena has been reported by other investigators, the reason remains unclear.

Total Kjeldahl nitrogen (TKN) showed a marked increase from the dredge inlet to the discharge. Also, similar to COD, the TKN showed an increase upon reaching the outlet weir.

Volatile solids were found to be mostly (90 percent) in the dissolved state. As shown, volatile solids were much higher in the deep (35-foot) saline water than in the shallower fresh water. Further examination of the data is needed for all the indicators of organic material (COD, TKN, and volatile solids) to gain an understanding of the nature and behavior of the organic materials.

Mercury analyses indicated that most of the mercury (70 percent) exists in the particulate phase. Analyses indicate that the mercury decreased while passing through the dredge system. Zinc appeared to exist primarily in the particulate phase and showed a slight decrease on passing through the dredge-diked area system. It should be noted that the highest levels of zinc were found in the deep saline waters. Lead was found at the lower limits of detection and showed no increase due to dredging.

Based on data available at this writing, it appears that dredging in Mobile River did cause a decline in dissolved oxygen and pH levels. The diked-land disposal area did appear efficient in returning these levels to normal. The diked area also appeared efficient in removing particulate matter, as evidenced by the drop in turbidity readings at the weir. However, visual inspection revealed that the high color values at the weir, when compared to Mobile River values, were largely due to suspended colloidal matter. Further inspection of the data will allow comparison of the chemical concentrations of this colloidal matter with that normally suspended in the river water. Mobile River exhibited a marked salinity wedge and the deep saline waters had high concentrations of phosphate, COD, volatile solids, and zinc when compared to the shallow, fresh waters. Subsequent analyses of bottom sediments will shed more information on this finding. It does appear based on this early evidence, that dredging did not cause marked migration of heavy metals from the particulate matter to the dissolved phase. However, all comments presented

here are subject to change pending final examination of all the results.

C. Channel Construction in an undisturbed area of the Bay.

This study is being conducted by the Marine Sciences Institute, University of Alabama (now the Marine Environmental Sciences Consortium), under contract with the Corps of Engineers. The study will be accomplished in four (4) stages:

1. Before channel construction begins conduct a 36-hour survey of:

   a. Biota

      (1) Benthic samples - 1 series, 22 stations

      (2) Planktonic samples - 6 hour intervals

      (3) Primary productivity of grass beds - 6 hour intervals

      (4) Primary productivity of phytoplankton - 6 hour intervals

   b. Hydrological Sampling

      (1) Temperature

      (2) Salinity

      (3) Dissolved oxygen

(4) Turbidity

(5) Current flow

c. Sediment load and siltation

(1) Baseline sediment identification and load

(2) Establish silt trap stations in grass beds

2. During construction, conduct two 36-hour surveys to measure sediment load and productivity along with surveillance of other biological and physical stations previously established.

3. Shortly after completion of project, conduct one 36-hour survey of all stations previously established plus sediment load and primary productivity measurements.

4. Survey residual effect of construction approximately six months following completion of the project, again conduct one 36-hour survey making the same observations and measurements as specified in the other stages of this study.

An interim report will be submitted by July 31, 1972, and a final report will be submitted by November 31, 1972.

D. Buried-Reef Shell Dredging.

The base line investigation included a one-day investigation of the shell dredging operation during typical operating conditions. The objective of this effort was to characterize the effect of shell dredging upon water quality. Two sediment core samples were taken in the vicinity of the dredge (Table 3) while water quality samples (Table 10) were collected in the discharge plume; all samples were collected within approximately one hour. The samples collected in the plume were taken at varying distances from the dredge approximately six inches up from the bottom. Analyses were performed on both filtered and unfiltered portions. A control station was selected well outside the influence of the shell dredge.

This brief investigation is not adequate to support definitive conclusion, but the data are indicative of what is taking place. Based on filtered and unfiltered analyses, the high concentrations of materials analyzed are apparently not dissolved into the water, through the dredging process, but stay tied to the suspended solids. The distribution

TABLE 10.

SHELL DREDGE
WATER SAMPLES

SEWL Log No.	Feet From Discharge	Station	Sample Date	Total Suspended Solids(mg/1)	Vol. Suspended Solids(mg/1)	Cr (ug/1)	Zn (ug/1)	Phenols (mg/1)	COD (mg/1)
3792	0	#1	11/3/71	53,900	3,820	890	1,580	5	4,290
		#1 Filtered	11/3/71			<50	67		<250
3793	100	#2	11/3/71	11,100	1,090	860	1,500	20	1,160
		#2 Filtered	11/3/71			<50	65		<250
3794	500	#5	11/3/71	143,000	9,260	4,000	1,700	28	14,600
		#5 Filtered	11/3/71			<50	67		<250
3795	800	#12	11/3/71	3,620	250	75	80	11	440
		#12 Filtered	11/3/71			<50	67		<250
3796A	1200	#24	11/3/71	2,460	185	140	200	14	800
		#24 Filtered	11/3/71			<50	66		<250
3796	1600	#33	11/3/71	1,300	110	610	1,250	10	540
		#33 Filtered	11/3/71			<50	42		<250
3797	2000	#37	11/3/71	402	37	60	80	<5	<250
		#37 Filtered	11/3/71			<50	63		<250
3798		Background	11/3/71	44	19	<50	65	<5	<250
		Background Filtered	11/3/71			<50	72		<250
3799		D/Olive Bay	10/8/71	19	3	<50	40		<250
3800		Dredge Tailings	11/4/71	7,280	685	510	720	46	796

Samples were collected 6 inches up from bottom

mg/l=ppm
ug/l=ppb

of suspended solids seems to be related to the entire effect that the dredge has upon water quality, which includes dissolved oxygen, chemical oxygen demand, zinc, volatile solids and others. There does not appear to be any simple relationship between constituents in the sediments and effects upon water quality.

At this particular sample period and location in the bay, the dredging operation increased particulate matter above ambient levels out to a distance of at least 2000 feet.

This one set of data is only a small part of a more comprehensive study now underway. The completion of this study will be used to conclude whether or not the indications of the short-term study are valid. At this time there do not appear to be any gross effects which indicate serious environmental damage.

A comprehensive environmental assessment is being made of the shell dredge in order to prepare an environmental impact statement on the operations.

Studies conducted by the Alabama Marine Resources Laboratory and participated in by the Technical Committee will supply a portion of the data required to prepare the statement while the balance of the environmental data are being collected by the Gulf South Research Institute, under contract to Radcliff Materials, Inc.

This total effort will define the effect of the buried reef shell dredging upon:

1. Water quality
2. Sediment quality and transport
3. Flora and Fauna
4. Physical features of the Bay
5. Noise
6. Solid waste

Data are being collected to define the zone of influence of the dredging operation under extreme conditions of wind and tide, such as wind from each quadrant imposed upon a flowing and ebbing tide. The zone of influence of the dredge is defined as the extreme limits of the suspended solids cloud, where concentrations reach ambient levels. Limits of the suspended solids cloud will be documented

both horizontally and vertically under conditions described above. That fraction of the materials which does not settle out, such as the colloidal particulates will be documented in terms of concentration, dispersion, and quality.

The effect of the suspended solids cloud upon the water column must be evaluated and it must be demonstrated whether or not the exposure of the sediment to the water column results in a significant change of concentration in either the total or the dissolved fractions, for the following parameters:

a. Heavy metals
   - Mercury
   - Lead
   - Zinc
   - Others

b. Pesticides:
   - Chlorinated hydrocarbons
   - Organo-phosphates
   - Poly-chlorinated biphenyls

c. Other parameters:
   - Volatile solids
   - Chemical oxygen demand

Biochemical oxygen demand

Nitrogen

Oil and grease

Turbidity

pH

D.O.

Temperature

The overburden and bottom materials moved by the dredge are being analyzed for quality and composition both in the areas where future dredging will be conducted and in past dredging areas. Data will show if in-place densities have changed and whether or not the operation has affected the susceptibility of the material to resuspension. Sediment samples and marine core borings used for this purpose will be collected on a 2-mile grid system within all permit areas.

As described before, the maximum limits of sediment transport under varying conditions must be accurately defined. Suspended solids including colloidal particulates, will be qualitatively characterized throughout this transport distance, both vertically and horizontally.

Turbidity changes resulting from the operation will be accurately documented and will be compared to turbidity changes resulting from weather conditions.

Benthic communities are being sampled at stations established for core and sediment samples on the 2-mile grid system. Data will be obtained which will document benthic communities in terms of species abundance, biomass, diversity, and size distribution. The species data will include polychaetes, crustaceans, foraminiferans, ostracods, diatoms, and mollusks.

In addition to the biological data taken on the grid stations, old dredge cuts will be surveyed to determine recolonization of species on previously dredged areas 1-month, 6-months, 1-year, 1.5-years, 2-years, 3-years, and 5-years old. Primary production of each of these areas will be documented. Sediment quality analyses will be taken to correlate with biological communities.

Grass beds within the permit area will be documented and evaluations made as to the effect of the dredging operation upon the growth and productivity of grass bottoms.

Documentation will be made as to whether or not this project affects any rare or endangered species of flora and fauna.

Data will be taken which documents the bottom contours of previously dredge areas. Evaluations will be made of the effects of this project upon current and salinity patterns.

Noise levels generated by the dredging operations will be measured at times when sound travel will be optimum. Documentation will be made at night when the dredge is fully operating and weather conditions are calm.

A report will be made on the method used for solid waste disposal and the system used to monitor its operation.

TABLE 11. PROGRESS ON PROJECT STUDY UNITS (Bar indicates extent of progress)

Study Unit	STATUS				
	Sampling	Analysis	Interpretation & Report	Expected Completion	Responsible Agency
I. Sediment Sampling					EPA
II. Resurvey State Stations					EPA
III. Deep Core Program					AGS
IV. Dredging Operations					
A. Open-Water Disposal					ADCNR, EPA, CE
B. Diked-Land Disposal					
1. Sediment Samples		70%		11/1/72	CE(v)
2. Water Samples				11/1/72	
C. Undisturbed Area (D'Olive)					MSI(MESC)
1. Before Const.				Interim	
a. biological				Report	
b. hydrological				7/31/72	
c. sediment load					
2. During Const.				Complete	
a. biological			50%	work 9/1/72	
b. hydrological			50%	Report upon	
c. sediment load			50%	completion #4	
d. productivity			50%		
3. After Const.				Complete	
a. biological				work 10/1/72	
b. hydrological				Report upon	
c. sediment load				completion #4	
d. productivity					

TABLE 11 CONTINUED.

Study Unit	STATUS				
	Sampling	Analysis	Interpretation & Report	Expected Completion	Responsible Agency
4. Residual Effects				Complete work 2/73	
a. biological					
b. hydrological					
c. sediment load					
d. productivity					
D. Buried Shell Dredging				11/1/72	ADCNR*, GSRI, CE, EPA
1. Preliminary Sediment Study	■	■	■		
2. Preliminary Water Study	■	■	■		
3. Extensive Sediment Study					
a. future dredging areas					
b. past dredging areas					
4. Extensive Water Study					
5. Benthic Communities					
6. Recolonization old dredge cuts					
a. biota					
b. productivity					
c. sediment quality					
7. Effects on grass beds					
8. Post-dredging bottom contours					

AGENCY ABREVIATION KEY:

EPA - Environmental Protection Agency, S.E. Water Lab & Mobile Office
AGS - Alabama Geological Survey
ADCNR - Alabama Department of Conservation and Natural Resources
CE - U.S. Army Corps of Engineers, Mobile District
CE(v) - Corps of Engineers, Vicksburg, Miss. Waterways Experiment Station
MSI(MESC) - Marine Science Institute, University of Alabama (now Marine Environmental Sciences Consortium)
GSRI - Gulf South Research Institute

* STUDY LEADER

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